5-2001

# Neuromotor and Cognitive Development in Children with Cerebral Palsy in Relation to Neural Plasticity

Vaniecea Pollard

Honor Thesis Committee

Approval for Submission

**Neuromotor and Cognitive Development in Children with Cerebral Palsy in Relation to Neural Plasticity**

**Vaniecea Pollard**

Dr. John K. Coleman (Committee Chairperson): _____

Dr. K.J. Abraham: _____

Dr. Zola J. Drain: _____

# Honors Thesis Project:

# Neuromotor and Cognitive Development in Children with Cerebral Palsy in Relation to Neural Plasticity

**Vaniecea Pollard**

**Abstract:**

Infants with neurological disabilities, such as cerebral palsy (CP) and Down syndrome (DS), show severe delays in motor and cognitive development relative to chronological age. Involvement of neural plasticity as a treatment of such neurological disorders is increasingly being seen. Previous studies have found that interventions involving sensory linked motor performance have been critical in facilitating motor improvement. The purpose of this study was to compare self-initiated mobility in children with CP and DS. Three infants, ages 8, 9, and 22 months, with diagnoses of no CP, DS, and CP respectively, participated in the study. The infants were videotaped in 5-minute trials using the Self-Initiated Prone Progression Crawler (SIPPC), a mobility aid that assists in infant crawling. Each recorded trial was coded and scored using the Mobility Scale. Movement and speed data from the trials showed the infants with CP and DS performed with less amplitude and purpose when compared to the typically developing child. Differences were also noted in the child with CP, displaying the lowest scores in coordination and movement. Asymmetry was also noted in the initiation movements of the children with CP and DS. However, overall test scores improved over time, suggesting that the SIPPC is an effective tool, taking advantage of experience-expectant and experience-dependent characteristics of learning and skill acquisition.

**Objectives:**

- Report the increasing incidence of premature birth and the complications that arise from prematurity.
- Define Cerebral Palsy

- Explore techniques that aid in the early intervention and diagnosis of children with neurological disabilities
- Explain the importance of neural plasticity in treating such disabilities
- Research treatments that improve neuromotor and cognitive development in young children with Cerebral Palsy and Down syndrome.
- Determine the effectiveness of the Self-Initiated Prone Progression Crawler (SIPPC) in relation to the concepts of neural plasticity for treatment of neurological disorders such as Cerebral Palsy.
-

**Terms Defined:**

- Acute Hypoxic Intrapartum Asphyxia: A severe state of oxygen deficiency within the uterus, which is sufficient to cause an impairment of function to the fetus.
- Cerebral Palsy (CP): Term used for a group of non-progressive disorders of movement and posture caused by abnormal development of, or damage to, motor control centers of the brain. CP is caused by events before, during, or after birth.
- Cognitive Development: The development of thought processes, including remembering, problem solving, and decision-making, from childhood through adolescence to adulthood.
- Diplegia: Refers to paralysis affecting one part of the body and the corresponding part on the other side of the body.
- Down Syndrome: Also known as Trisomy 21; A chromosomal disorder caused by the presence of all or part of an extra 21st chromosome. It is named after John Langdon Down, the British doctor who described the syndrome in 1866. The condition is

characterized by a combination of major and minor differences in structure. Often Down syndrome is associated with some impairment of cognitive ability and physical growth as well as facial appearance. Down syndrome in children can be identified with amniocentesis during pregnancy or at birth.

- Encephalitis: Inflammation of the brain.
- Extremely Low Birth Weight (ELBW): Infants weighing less than 2.2 lbs or one kilogram at birth are classified as extremely low birth weight babies.
- General Movements (GMs): Movements that form the basic motility of young infants; have been linked to neurological outcomes following disease and/or injury of the brain.
- Hemiplegia: A condition in which one-half of a patient's body is paralyzed. Hemiplegia is more severe than hemiparesis, wherein one half of the body is weakened, but not paralysed.
- Meningitis: Inflammation of the membranes of the brain or spinal cord. A disease that may be either a mild illness caused by any of numerous viruses, or a more severe usually life-threatening illness caused by a bacterium. Associated with fever, headache, vomiting, malaise, and stiff neck.
- Mobility Scale: Tool developed during the course of this project, that asses child motor and cognitive function based on six criteria: Child Cues, Child/Toy Interaction, Caregiver/Child Interaction, Child Motor Function, SIPPC Movement, and Qualitative Observation.
- Monoplegia: Paralysis of a single limb, usually an arm.

- Neuron: One of the cells that constitute nervous tissue, that have the property of transmitting and receiving nervous impulses, and that are composed of somewhat reddish or grayish protoplasm with a large nucleus containing a conspicuous nucleolus, irregular cytoplasmic granules, and cytoplasmic processes. They are highly differentiated frequently as multiple dendrites or usually as solitary axons and which conduct impulses toward and away from the nerve cell body.
- Neural Plasticity: A term referring to the brain's ability to learn, remember and forget, and its capacity to reorganize and recover from injury.
- Paresis: A condition typified by partial loss of movement, or impaired movement.
- Preterm Labor/Birth: Preterm or premature labor occurs when the uterus begins to contract causing the cervix to dilate before 37 weeks gestation
- Primitive Reflexes: Various simple, stereotypic, automatic neuromuscular responses characteristic of the mature fetus and newborn but typically inhibited during the first year of life. Primitive reflexes are directed by brainstem centers and include the startle (Moro), rooting, and tonic neck reflexes. Abnormal persistence can lead to clumsiness, in-coordination, and perceptual difficulties.
- Self-Initiated Prone Progression Crawler: Mobility tool designed to take advantage of experience-expectant and experience-dependent characteristics of neural plasticity by increasing the potential for motor learning and skill acquisition.
- Subdural Hematoma: A collection of blood on the surface of the brain. It lies beneath the outer covering (the dura) of the brain and the brain's surface; usually the result of a serious head injury.

- Synapse: The functional membrane-to-membrane contact of the nerve cell with another nerve cell, an effector (muscle or gland) cell, or a sensory receptor cell. The synapse serves the transmission of nerve impulses.
- Typically Developing (TD): Children that regularly pass predictable physical and cognitive milestones along the course of growth and development.
- Very Low Birth Weight (VLBW): Infants weighing less than 3.3 lbs at birth are classified as very low birth weight babies. Approximately 1% of babies in the U.S. weigh less than 3.3 lbs. at birth.

**Review of Literature:**

Although there have been significant technological advances in the field of medicine over the past twenty years, there has been little to no improvement in solving the problem of preterm delivery or the premature rupture of membranes (PROM). A typical pregnancy lasts approximately 40 weeks from the date of the last menstrual cycle, or 38 weeks after fertilization. Preterm or premature labor occurs when the uterus begins to contract causing the cervix to dilate before 37 weeks gestation. Currently, there is not an accurate way to predict which women will go into labor early. Consequently, there is also no way to prevent premature delivery in women who have been determined to be at risk. Unfortunately, the number of preterm babies born in the United States has risen dramatically within the past decade. Between 1994 and 2004, the rate of preterm delivery has increased 14 percent. In 2004, approximately 12.5% of live births in the U.S. were premature (National Center for Health Statistics, 2007). The dangers of preterm birth are the risks associated with premature babies. Premature newborns are at risk of complications associated with under-developed organs and organ systems. The younger the gestational age of the premature

child, the greater the risk of serious medical complications. Children born younger than 32 weeks gestation are considered to be at greater risk than those born after 32 weeks. In addition, children born before 24 weeks of pregnancy have an increased mortality rate (Health Wise, 2007). However, children that survive very preterm birth are prone to long term health and developmental problems.

Increased technological and clinical advances in the field of medicine have not decreased the number of premature births in the country. Consequently, there has been a dramatic decrease in neonatal mortality in very low-birth-weight (VLBW) and extremely low-birth-weight (ELBW) infants within the past 20 years. However, there has also been a relative increase in the occurrence of cerebral palsy (CP) among children with low-birth-weight and short gestation (Fabrizio et al., 2002). In the United States, CP is considered the single most debilitating pediatric condition. An estimated 8,000 babies and infants are diagnosed with the condition each year. The instance is higher in VLBW and ELBW infants. In addition, some 1,200 to 1,500 preschool age children are recognized each year to have CP (United Cerebral Palsy, 2001). Cerebral Palsy is defined by Fabrizio et al. (2002), as "a chronic disability characterized by aberrant control of movement or posture, appearing early in life, and not the result of recognized progressive disease" (p.462). It is characterized by atypical patterns of movement and postural control, or lack thereof. Collectively, cerebral palsy is a term used to describe a group of chronic disorders that impair the ability to control movement and maintain balance and posture.

According to Citra and Nandini, there are four classifications of the disorder: monoplegic CP, hemiplegic CP, diplegic CP, and monoplegic CP. However, monoplegia and hemiplegia are relatively uncommon. Recent studies have found that diplegia is the

most common form of cerebral palsy, accounting for approximately 30% to 40% of known cases. Hemiplegia follows, accounting for approximately 20% to 30%, and quadriplegia accounting for approximately 10% to 20%.

Of the three most common forms of CP, quadriplegic CP is the most severe form. It involves all four limbs, however the trunk and upper limbs are more severely involved than the lower limbs associated with acute hypoxic intrapartum asphyxia. A child with quadriplegic CP exhibits very few voluntary movements, and vasomotor changes of the extremities are very common. Many children have difficulty swallowing, and often aspirate food material into the lungs. Approximately half of the patients with quadriplegia CP have optic atrophy, as well as seizures, and intellectual impairment is severe in all cases.

Hemiplegic CP, or spastic hemiparesis, is characterized by unilateral weakness of the upper limbs. It is seen in approximately 17% of premature infants. As with quadriplegic CP, voluntary movements of the upper limbs are severely impaired, with hand functions being the most affected. Sensory abnormalities in the affected limbs of children with hemiplegic CP are also common. Seizures occur in approximately half of known cases. In addition, many children suffer from visual field defects and cranial nerve abnormalities where facial nerve palsies are most commonly seen.

Spastic diplegia is most commonly associated with premature birth and low birth weight infants. Almost all preterm infants with diplegia show cystic periventricular leukomalacia (PVL) on neuroimaging scans. PVL is the most common brain injury in children born prematurely. In diplegic CP, lower limbs are more severely affected than the trunk and upper limbs. Children with this form of the disorder exhibit impaired dorsiflexion of the feet with increased tone in the ankles. In severe cases, there is flexion in the hips,

knees, and in some cases, the elbows. Rigidity in the lower limbs can been seen when the child is held vertically, and scissoring of the legs is often seen. Like quadriplegic and hemiplegic, seizures are often common. Fixation difficulties and blindness have also been associated with diplegic CP (Chitra & Nandini, 2005).

Cerebral Palsy is not a disorder with a single cause. As state above, it is a group of disorders involving movement and posture with a variety of causes. However, the underlying cause of CP is injury to one or more specific areas of the brain that control voluntary movement and posture control which occurs one of two ways: acquired or congenital. Acquired CP results from brain injury within the first few months or years of life stemming from such causes as brain infections (encephalitis or meningitis) and head injuries resulting in subdural hematoma (Mayo Foundation for Education and Research, 2004). Congenital CP results from brain injury during
fetal development. It is present and birth and is responsible for 70% of CP cases. Additionally, another 20% of children are diagnosed with congenital CP due to a brain injury that occurred during the birthing process (United Cerebral Palsy, 2001). Although congenital CP is present at birth does not mean that it is apparent. It is generally believed that CP is extremely hard or nearly impossible to diagnose in children less than 6 months of age, except in very severe cases of the condition (Chitra & Nandini, 2005). Early signs of CP usually appear before 18 months of age and are generally noticed by the child's parents are primary care givers. Infants with CP frequently reach developmental milestones at a much slower pace and with substantial impairment in the formation and development of the control over movement patterns as compared to typically developing (TD) infants (Mahoney, Robinson, Fewell, 2001). Also, infants with CP have been known to have a

delayed disappearance of the primitive reflexes, absent postural reactions, and other characteristic movements linked to their condition (Zafeiriou et al., 2004). Primitive reflexes and postural reactions are a part of the earliest and most frequently used neurological examinations of young infants and children. In a recent review on primitive reflexes and postural reactions, Zafeiriou et al. (2004) concluded that the combined examination of primitive reflexes and postural reactions in conjunction with motor developmental milestones and evaluation with standard developmental screening tests constitute a solid basis for the evaluation and diagnosis of neonatal and infantile motor disorders. In a 2002 study on general movements (GMs) in infants with CP, Fabrizio et al., found that consistent and predominant cramped synchronized GMs specifically predict CP in young infants. Based on the study's findings, Fabrizio also concluded that the earlier cramped synchronized GMs appear in infants with CP, the worse the child's later impairment will be. In both studies, the authors address the importance of detecting the early signs of CP and predicting the condition in young infants. Early prediction, diagnosis, and intervention play a key role in the management and rehabilitation of children with CP.

Birth defects and genetic abnormailites can cause obvious problems affecting growth and development. Down Syndrome (DS), named after 19th century physician John Langdon Down, is a syndrome-complex of genetic origin with multiple neurodevelopmental and neurophysical manifestations (Capone, 2004). According to the Centers for Disease Control (CDC), DS occurs in approximately in every 800 live births, and is considered the most common genetic cause of mental retardation in the United States. There are more than 50 clinical signs in children with DS such as: decreased muscle tone at birth, slanting eyes with folds of skin at the inner corners (epicanthal folds), hyperflexibility, small heads

(microcephaly), flattened nose, small oral cavity with protruding tongue, separated cranial sutures, broad hands with shortened fingers and a

single crease in the palm (simian crease), and delayed mental and social skills. However, it is rare to find all or even most of them in a single person (National Dissemination Center for Children with Disabilities, 2005; National Institute of Health, 2004). As well as suffering from cognitive deficits and physical anomalies, children with DS are also at greater risk for medical complications specific to their condition, such as an increased frequency of congenital heart disease, grastrointestinal disorders, and increased instances of leukemia (National Institue of Neurological Disorders and Stroke, 2005). Unlike children with CP, whose condition is caused by injury to the brain during fetal development or during early infancy, children with DS develop their condition genetically. Children with DS are often identified and diagnosed soon after birth, and even sometimes before birth. Genetic testing for women at risk of conceiving a child with DS can be performed during pregnancy. However, in most cases, the diagnosis of DS is made according to results from a chromosome test administered shortly after birth (National Dissemination Center for Children with Disabilities, 2005).

The cause of DS is associated with the trisomy of chromosome 21. The extra copy of this chromosome is most commonly caused by an error in cell division called disjunction. However, two other types of chromosomal abnormalities, mosaicism and translocation are also implicated in DS (National Down Syndrome Society, 2006). Although parents of any age may have a child with DS, the incidence is higher for women of advanced maternal age (35 years or older) due to the aging and degeneration of genetic material of the ovum. Trisomy of chromosome 21 causes the misexpression of hundreds of genes, many or

all of which contribute to the pathogenesis and phenotype of DS (National Institute of Neurological Disorders and Stroke, 2005; Capone, 2004). Although the cause of DS is known, the understanding of how the trisomy of chromosome 21 leads to the development of microcephaly, cognitive and speech impairment, and neuromotor dysfunction such as hypotonia, diminished reflexes, and motor delays, remains poorly understood (Capone, 2004).

Most infants and toddlers with DS show severe developmental delays relative to chronological age. Children with DS move through stages of early motor and cognitive development more slowly and exhibit more in group variability as compared to typically developing (TD) children of the same age. It has also been observed that children with DS show

delays in the emergence and termination of primitive reflexes (Fidler, Hepburn, Mankin & Rogers, 2005). Children with DS also show poor development of praxis skills. Praxis is the planning, execution, and sequencing of movements. Early praxis skills, such as the planned reaching for an object, develop within the first year of life for TD children (Fidler et al., 2005).

Delay in the early development of praxis may impact neuromotor and cognitive development in children with DS. The effect of early intervention in children with DS is crucial to their neurological and cognitive development. By 18 months of age, abnormalities in the development of dendritic spines are seen in children with DS. Decreases in spine density as well as abnormally larger or thinner spines have also been observed. Such abnormalities are consistent with the memory deficits seen in children with DS, as well as

abnormalities in synaptic plasticity (National Institute of Neurological Disorders and Stroke, 2005).

The management of CP is directed at repair of the injured brain and the management of the physical disability as a result of brain damage sustained early in life (Goldstein et al., 2004). The findings of Fabrizio et al. (2002) and Zafeiriou et al. (2004) suggest that early detection and diagnosis of CP in young infants increases the potential for improved neuromotor and cognitive development. Typically developing (TD) children, as well as children with CP, have an increased

aptitude for learning and developing memory. Children have also displayed an astonishing ability to recover from brain early brain injury (Kulak et al., 2005). In a 2004 article, Goldstein et al. discusses the involvement of neural plasticity as an approach in the treatment of CP. The term neural plasticity refers to the brain's ability to learn, remember and forget, and its capacity to reorganize and recover from injury (Kulak et al., 2005). A treatment approach stemming from the concept of neural plasticity involves developing the use of other neurological pathways to take over the function of the damaged areas in the brain (Goldstein et al., 2004). The functional anatomy of the brain synapses is continually transforming in response to changes in the neuron's environment. These changes can be triggered by stimulation from the sensory systems (i.e. touch, sound, etc.). According to Goldstein et al. (2004), such constant neurological change is the basis of learning during development, and allows the brain to gain new or improved skills in controlling motor coordination. Goldstein also states, "Sensory input linked to motor performance is a critical factor in bringing about desired motor improvement…programmed repetition is one means of teaching the brain to improve motor performance skills"(p.43). The concept of neural

plasticity is of great significance to the management of CP in children. It indicates that children with have the ability, through repetitive sensory stimulation, to reconfigure and produce new or improved neurological circuits to assume the functions of damaged areas in the brain leading to enhanced motor function and coordination. It is also know that a considerable degree of synaptic selection and reorganization occurs during the first 5 years of a child's life. This implicates early intervention and the use of neurobiological based therapies during critical periods of neurological and cognitive development (Capone, 2004). For children with delayed motor function, such as those with CP or DS, the major goal of early intervention is to enhance the rate of acquiring motor skills, and to prevent the occurrence of secondary problems resulting from the use of compensatory strategies such as "fixing" or "locking" joints to over come the effects of decreased motor tone (Mahoney et al., 2001). Because infants and toddlers with DS are invariably identified soon after birth, unlike the majority children with CP, a window of opportunity may exist during which carefully targeted intervention could produce a more favorable neurocognitive outcome (Capone, 2004).

For children with CP and DS, the concept of neural plasticity is of great importance. It implies that children with neurological disabilities, such as CP and DS, are able to create improved neurological circuits through repetitive sensory stimulation to overcome motor impairment. However, the key to improving neuromotor and cognitive development in both types of children is early diagnosis and intervention. With early interventive and rehabilitative techniques, the development of increased motor control and function for children with CP and DS will greatly improve, allowing them to reach developmental

milestones with less delay as compared to their TD peers. Such developmental progress will eventually lead to greater independence in later childhood and adulthood.

**Introduction:**

Infants with neurological disabilities, such as cerebral palsy (CP) and Down syndrome (DS), show severe delays in motor and cognitive development relative to chronological age. Treatments and interventions of these conditions are directed at promoting plasticity of the injured brain and the management of the physical disability. Like typically developing (TD) children, children with CP and DS have an increased aptitude for learning. Because children have also displayed an astonishing ability to recover from early brain injury, increasingly intervention efforts are geared towards influencing neural plasticity in children like those with CP. Such treatment efforts have explored ways to increase neuron size and synaptic function by engaging a variety of sensory and cognitive systems and promoting the use of other neurological pathways to take over the function of the damaged areas in the brain. Previous studies have also found that interventions involving person-generated efforts to move are critical in facilitating motor improvement. This study compared self-initiated mobility in children with CP and DS using the Self-Initiated Prone Progression Crawler (SIPPC). The purpose of this study was to determine the effectiveness of the Self-Initiated Prone Progression Crawler (SIPPC) in relation to the concepts of neural plasticity for treatment of neurological disorders such as Cerebral Palsy. It was hypothesized that the SIPPC will take advantage of experience-expectant and experience-dependent characteristics of neural plasticity by increasing the potential for motor learning and skill acquisition.

**Materials & Methods:**

Three infants, ages 8, 9, and 22 months participated in the study. The 8 month old was TD, the 9 month old had a diagnosis of DS, and the 22 month old had a diagnosis of CP. Each of the 3 infants was videotaped using the SIPPC, a mobility aid that assists infant crawling. The SIPPC consists of a wheeled platform with two interdependent drive wheels controlled by an on-board computer that assists the infant with multi-directional propulsion efforts. Load cells are embedded on the platform to record information about the infant's movements. Protocol for recording included 3 successive phases: familiarity of the SIPPC, therapists moving the SIPPC, and self-initiated trials by the infants. Each self-initiated trial was allotted a maximum of 5 minutes. For this aspect of the study, the recorded trials were coded and scored using the Mobility Scale, a tool developed during the course of this project, that asses child motor and cognitive function based on six criteria: Child Cues, Child/Toy Interaction, Caregiver/Child Interaction, Child Motor Function, SIPPC Movement, and Qualitative Observation. The data collected from the SIPPC load cells and on-board computer are not presented, and are presented elsewhere. Reliability of the Mobility Scale was calculated by comparing the results of two trials completed by two individuals at different times. Percentages were calculated by the number of discrepant answers versus the number of matching answers for both sets of trials, yielding a percent agreement of 95%. A total of 25 five trials were videotaped and coded for this study. The children with CP and DS had 10 trials each. The typically developing child had 5 trials.

**Results:**

Data from the recorded trials using the Mobility Scale showed that the child with CP displayed the lowest scores in coordination and movement. Unlike the typically developing

infant, the infants with CP and DS exhibited asymmetrical initiation movements. The child with CP initiated movement more frequently with the left side, and the child with DS with the right. Overall Mobility Scale scores varied between each child. For the typically developing child, scores steadily increased over the first 3 trials, and began to decline again at trial 4. For the child with DS, scores increased and decreased at varying intervals. The child with CP displayed a general increase in test scores over time. However, the motor scores showed an increase over time for all of the children.

**Discussion:**

The concept of neural plasticity is of great significance to the management of neurological disabilities such as CP and DS. It indicates that with repetition of a task-oriented activity and through repetitive sensory stimulation, these children have the ability to learn a new skill. The findings may suggest that they are able to reconfigure and produce new or improved neurological circuits that will in turn assume the functions of the damaged areas in the brain leading to enhanced mobility. Because mobility during infancy promote the development of other systems, such as vision, arousal, vestibular function, and perceptual cognition, failure to develop motor function may result in wide-ranging limits to developmental outcomes. Use of the SIPPC bypasses the mobility constraints experienced by infants with such neurological disabilities, and helping to facilitate in other domains of development.

**Conclusion:**

Overall the expected variability in the infants' motor strategies and the observed changes over time suggest that the SIPPC has the potential to positively influence motor function. The use of the device appears to take advantage of experience-expectant and

experience-dependent characteristics of neural plasticity by increasing the potential for motor learning and skill acquisition. However, multiple teaching and practice opportunities are required before infants with CP and DS can be able to effectively move and drive the SIPPC. the key to improving neuromotor and cognitive development in both types of children is early diagnosis and intervention. With early interventive and rehabilitative techniques, the development of increased motor control and function for children with CP and DS will greatly improve, allowing them to reach developmental milestones with less delay as compared to their TD peers. Such developmental progress will eventually lead to greater independence in later childhood and adulthood.

**Acknowledgements:**

Thubi H. A. Kolobe, P.T., Ph.D.

Department of Rehabilitation Sciences, University of Oklahoma Health Sciences Center, Oklahoma City, OK

John K. Coleman, Ph.D.

Department of Chemistry, Langston University, Langston OK

K.J. Abraham, Ph.D.

Department of Biology, Langston University, Langston OK

Zola J. Drain, Ph.D.

Department of Biology, Langston University, Langston OK

References

Capone, G. T. *Down Syndrome Genetic Insights and Thoughts on Early Intervention.* Infants and Young Children 17 (2004): 45-59. 12 March 2007.

*Cerebral Palsy: Facts & Figures.* United Cerebral Palsy. 2001. 13 March 2007 <http://www.upc.org>.

*Cerebral Palsy.* Mayo Foundation for Education and Research. 2004. 13 June 2007 <http://www.mayo.edu/education>.

Chitra, S., and M. Nandini. *Cerebral Palsy- Definition, Classification, Etiology, and Early Diagnosis.* Indian Journal of Pediatrics 72 (2004): 865-868. 7 March 2007.

*Developmental Disabilities: Down Syndrome.* National Dissemination Center for Children with Disabilities. 2005. 12 March 2007 <http://www.research.nichy.org>.

*Developmental Disabilities: Down Syndrome.* National Institutes of Health-National Library of Medicine. 2004. 12 March 2007 <http://www.nih.nlm.gov>.

*Down Syndrome: Toward Optimal Synaptic Function an Cognition.* National Institute of Neurological Disorders and Stroke. 13 Feb. 2005. 14 March 2007 <http://www.ninds.nih.gov>.

Ferrari, F., G. Cioni, C. Einspieler, F. Roversi, A. Bos, P. Paolicelli, A. Ranzi, and H. Prechtl. *Cramped Synchronize General Movements in Preterm Infants as an Early Marker for Cerebral Palsy.* Archives of Pediatric and Adolescent Medicine 156 (2002): 460-467. 11 March 2007.

Fidler, D. J., S. L. Hepburn, G. Mankin, and S. J. Rogers. *Praxis Skills in Young Children with Down Syndrome, Other Developmental Disabilities, and Typically Developing Children.* The American Journal of Occupational Therapy 59 (2005): 129-138. 12 March 2007.

Goldstein, M. "The Treatment of Cerebral Palsy: What We Know, What We Don't Know." Pediatrics 145 (2004): 42-46. 10 March 2007.

Golomb, M. R., B. P. Garg, and L. S. Williams. *Measuring Gross Motor Recovery in Young Children with Early Brain Injury*. Pediatric Neurology 31 (2004): 311-317. 8 March 2007.

Kulak, W., W. Sobaniec, J. Kuzia, and L. Bockowski. *Neurophysiologic and Neuroimaging Studies of Brain Plasticity in Children with Spastic Cerebral Palsy*. Experimental Neurology 198 (2005): 4-11. 10 March 2007.

Mahoney, G., C. Robinson, and R. Fewell. *The Effects of Early Motor Intervention on Children with Down Syndrome or Cerebral Palsy: a Field-Based Study.* Developmental and Behavioral Pediatrics 22 (2001): 153-162. 10 March 2007.

McKay, S., and R. Angulo-Barroso. *Longitudinal Assessment of Leg Motor Activity and Sleep Patterns in Infants with and Without Down Syndrome*. Infant Behavior and Development 29 (2006): 153-168. 12 March 2007.

Salokorpi, T., T. Rautio, N. Sajaniemi, S. Sirve, H. Tuomi, and L. Von Wendt. *Neurological Development Up to the Age of Four Years of Extremely Low Birthweight Infants Born in Southern Finland in 1991-94.* Pediatric Neurology 90 (2001): 218-221. 9 March 2007.

S. P. Chauhan, E. F. Magann, J. C. Morrison, and G. D. V. Hankins *Neonatal Organ System Injury in Acute Birth Asphyxia Sufficient to Result in Neonatal Encephalopath.* Obstet. Gynecol., (2003) 101(1): 203 - 204. 21 November 2007.

Vicari, S. *Motor Development and Neuropsychological Patterns in Persons with Down Syndrome*. Behavior Genetics 36 (2006): 355-364. 8 March 2007.

Vohr, B., M. Msall, D. Wilson, L. Wright, S. McDonald, and W. Poole. *Spectrum of Gross Motor Function in Extremely Low Birth Weight Children with Cerebral Palsy At 18 Months of Age.* Pediatrics 116 (2005): 123-129. 7 March 2007.

Zafeiriou, D. I. *Primitive Reflexes and Postural Reactions in the Neurodevelopmental Examination.* Pediatric Neurology 31 (2004): 1-8. 11 March 2007.

## Coded Scores by Sub-Category and Trial

| Sub-Categories | Typically Developing | | | | | Down Syndrome | | | | | | | | | | Cerebral Palsy | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tria l1 | Tria l2 | Tria l3 | Tria l4 | Tria l5 | Trial 1 | Tria l2 | Tr ial 3 | Trial 4 | Tria l5 | Tria l6 | Tria l7 | Tria l8 | Tria l9 | Tria l10 | Tria l1 | Tria l2 | Tria l3 | Tria l4 | Tria l5 | Tria l6 | Tria l7 | Tria l8 | Tria l9 | Tria l10 |
| I. Child Cues | 6 | 4 | 5 | 6 | 6 | 5 | 8 | 6 | 7 | 4 | 6 | 4 | 6 | 4 | 5 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 4 |
| II. Child/Toy Interaction | 3 | 5 | 5 | 5 | 3 | 4 | 4 | 4 | 3 | 5 | 3 | 4 | 5 | 3 | 3 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| III. Caregiver/Child Interaction | 7 | 10 | 10 | 11 | 11 | 9 | 8 | 8 | 9 | 10 | 10 | 7 | 9 | 8 | 10 | 0 | 0 | 0 | 6 | 7 | 8 | 7 | 8 | 9 | 8 |
| IV. Child Motor Function | 7 | 11 | 10 | 11 | 12 | 8 | 7 | 1 0 | 8 | 9 | 10 | 9 | 10 | 10 | 10 | 5 | 6 | 4 | 6 | 6 | 7 | 8 | 8 | 6 | 5 |
| V. SIPPC Movement | 10 | 16 | 18 | 14 | 13 | 8 | 9 | 1 3 | 6 | 12 | 12 | 10 | 8 | 9 | 11 | 8 | 5 | 5 | 5 | 6 | 6 | 7 | 11 | 10 | 9 |
| VI. Qualitative Observation | 15 | 21 | 22 | 21 | 17 | 13 | 10 | 1 7 | 13 | 15 | 19 | 13 | 16 | 16 | 18 | 11 | 11 | 8 | 11 | 13 | 10 | 13 | 15 | 15 | 11 |
| ∑ (Total Score) | 48 | 67 | 70 | 68 | 62 | 47 | 46 | 5 8 | 46 | 55 | 60 | 47 | 54 | 50 | 57 | 29 | 26 | 21 | 32 | 37 | 36 | 40 | 47 | 46 | 39 |

Figure 3. Mobility Scale scores for each infant by trial. For each sub-category, points were awarded based on infant performance. The overall score was calculated by adding the scores of each sub-category. Maximum number of possible points for the overall score is 96.

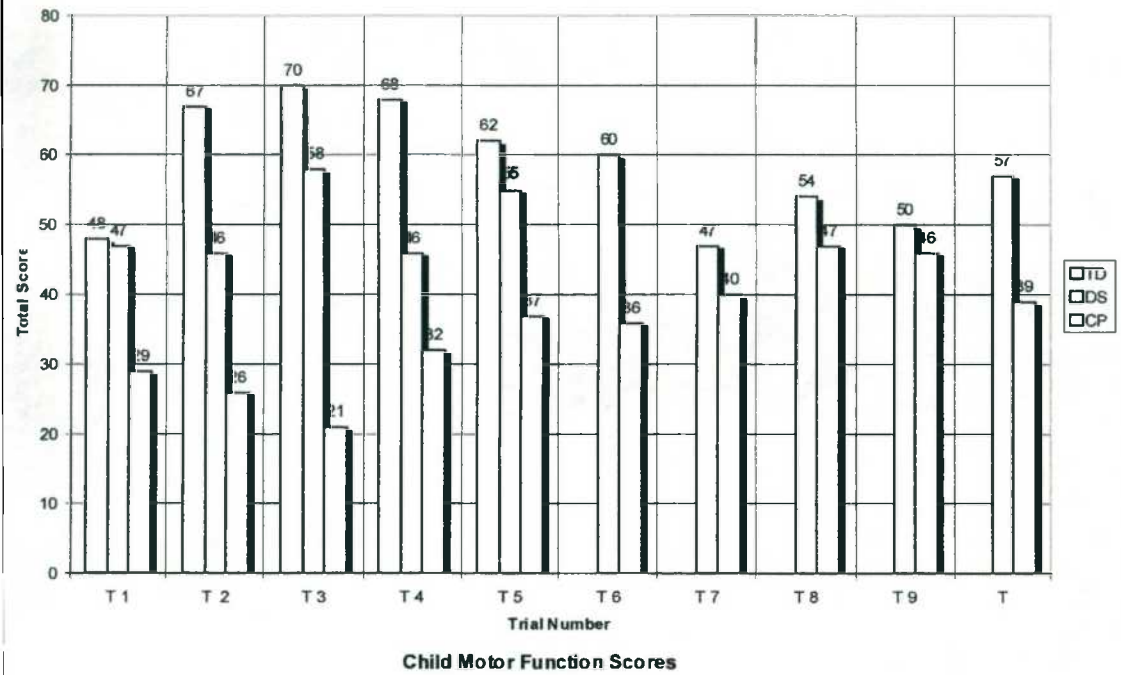



Figure 4: Overall mobility scores by trial. The typically developing child exhibits a steady increase in scores over time until scores begin to decrease at Trial 4. The child with DS exhibits a variance in test scores over time, and the child with CP exhibits a general increase in scores over time.

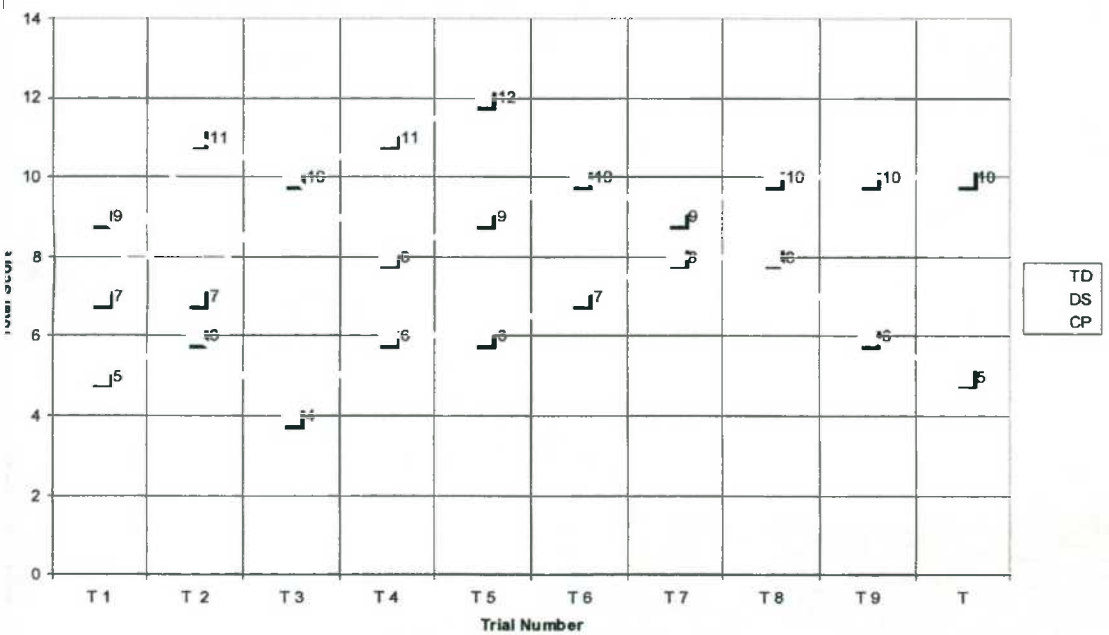
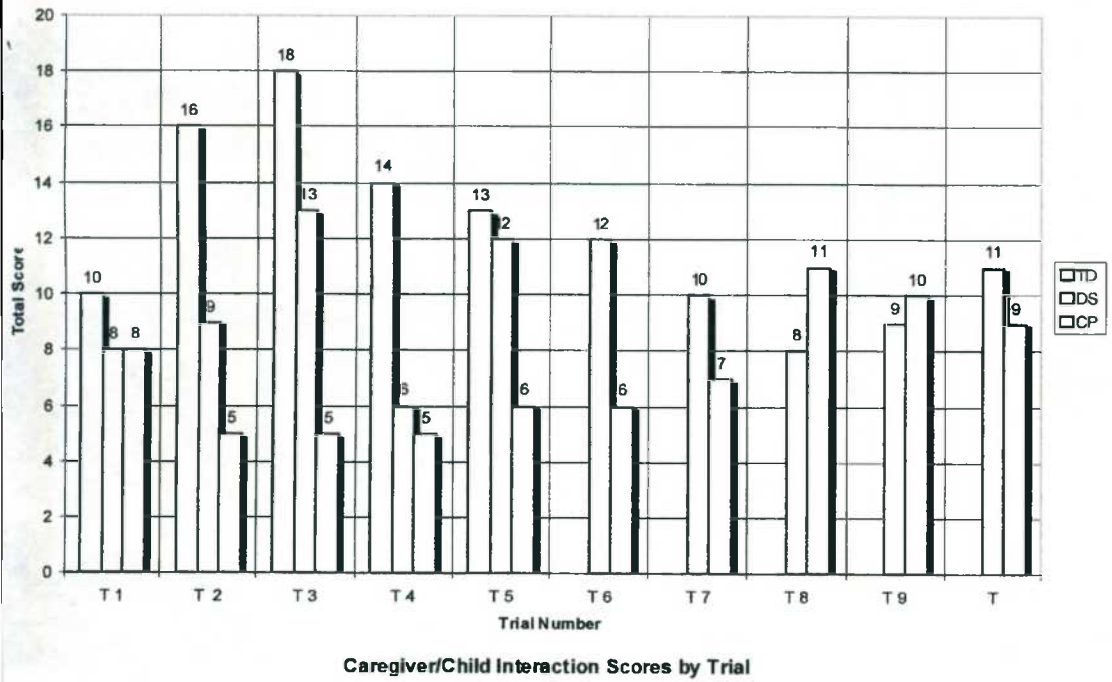



Figure 5: Child Motor Function Scores indicate the child's ability to move the SIPPC by trial. Sub-category assesses the child's use of motor skills during the trial, including initiation of movement, and head control. Each child exhibited a general increase in scores over time, except for the child with DS and CP, where scores did not change and decreased, respectively, at Trial 9.




Caregiver/Child Interaction Scores by Trial

Figure 6: SIPPC Movement scores by trial. Sub-category assesses how the child moves the SIPPC and the number of start/stop cycles in movement during the trial. The typically developing child exhibits a steady increase in scores over time until scores begin to decrease at Trial 4. The child with DS exhibits a variance in test scores over time, and the child with CP exhibits a decrease in test scores at Trial 2, no change in test scores until Trial 5 where scores begin to increase.

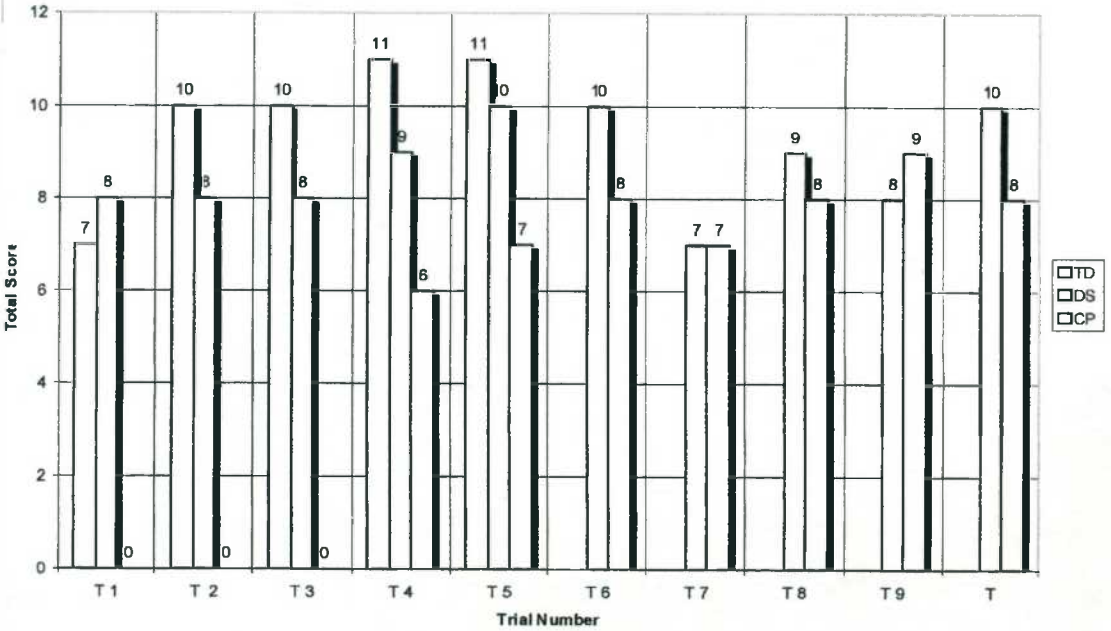



Figure 7: Caregiver/Child Interaction scores by trial. Sub-category assesses the interaction between caregiver and child, including child response to encouragement an praise. The typically developing child exhibits a relative increase in test scores over time. The child with DS exhibits a general increase over time until Trial 7, where scores decline and increase again at Trial 9. The child with CP exhibits a score of 0 for the first 3 trials and begins to have a general increase in scores at Trial 4.